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SPECIAL ISSUE PROSPECTIVE ARTICLES: 2D NANOMATERIALS FOR HEALTHCARE AND LAB-ON-A-CHIP DEVICES

Intracellular microRNA quantification in intact cells: a novel strategy based on reduced graphine oxide-based fluorescence quenching.

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Nanomaterials have been proposed as key components in biosensing, imaging, and drug delivery since they offer distinctive advantages over conventional approaches. The unique chemical and physical properties of graphene make it possible to functionalize and develop protein transducers, therapeutic delivery vehicles, and microbial diagnostics. In this study, reduced graphene oxide as a potential nanomaterial for quantification of microRNAs including their structural differentiation *in vitro* in solution and inside intact cells are evaluated. Results provide evidence for the potential use of graphene nanomaterials as a platform for developing devices that can be used for microRNA quantitation as biomarkers for clinical applications. DOI:org/10.1557/mrc.2018.120

Nickel-reduced graphene oxide composite foams for electrochemical oxidation processes: towards biomolecule sensing

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Metal–graphene composites are sought after for various applications. A hybrid light-weight foam of nickel (Ni) and reduced graphene oxide (rGO), called Ni-rGO, is reported here for small molecule oxidations and thereby their sensing. Methanol oxidation and non-enzymatic glucose sensing are attempted with the Ni-rGO foam via electrocatalytically, and an enhanced methanol oxidation current density of 4.81 mA/cm^2 is achieved, which is ~1.7 times higher than that of bare Ni foam. In glucose oxidation, the Ni-rGO electrode shows a better sensitivity over bare Ni foam electrode where it could detect glucose linearly over a concentration range of 10 μM to 4.5 mM with a very low detection limit of 3.6 μM. This work demonstrates the synergistic effects of metal and graphene in oxidative processes, and also shows the feasibility of scalable metal–graphene composite inks development for small molecule printable sensors and fuel cell catalysts. DOI:org/10.1557/mrc.2018.123

Flexible substrate sensors for multiplex biomarker monitoring

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Wearable healthcare technologies should be non-invasive, robust to daily activity/environments, easy to use, and comfortable to wear. Flexible substrate devices for biomarker monitoring can contribute to wearable diagnostic applications. Single-target biosensors have extensively been developed for health-monitoring applications; however, recently multiplex biomarker tests have generated clinical interest. Targeting multiple biomarkers in diagnostic systems (wearable or point of care) offers more focused diagnosis and treatment as changes in a single biomarker can be caused by a series of physiologic conditions. This review highlights flexible substrates that have been successfully demonstrated for multiplex biomarker detection with potential for healthcare monitoring. DOI:org/10.1557/mrc.2018.134

Challenges in fabricating graphene nanodevices for electronic DNA sequencing

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Graphene-based electronic DNA sequencing techniques have received significant attention over the past decade and are

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hoped to provide a new generation of portable, low cost devices capable of rapid and accurate DNA sequencing. However, these devices are yet to demonstrate DNA sequencing. This is partly due to complex fabrication requirements resulting in low device yields and limited throughput. In this paper, the challenging fabrication of graphene based electronic DNA sequencing devices is reviewed. A particular focus of common fabrication challenges and the development of high-throughput, high-yield fabrication of these devices is given. DOI:org/10.1557/mrc.2018.187

Multi-organ on a chip for personalized precision medicine

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The inefficiencies of the current pipeline from discovery to clinical approval of drugs demand a surrogate method to indicate adverse drug reactions, e.g., liver damage. Organ-on-chip (OOC) models would be an ideal, rapid, and human-specific alternate, which would render animal testing obsolete. The ground-breaking ability of OOCs and Multi-OOC constructs is the accurate simulation of the *in vivo* conditions of human organs leading to precise drug screens for cytotoxicity and/or drug efficacy at a faster pace and lesser cost. Here, the innovation, architecture, and the progress of OOCs towards human body-on-a-chip are discussed. DOI:org/10.1557/mrc.2018.148

SPECIAL ISSUE RESEARCH LETTERS: 2D NANOMATERIALS FOR HEALTHCARE AND LAB-ON-A-CHIP DEVICES

An emerging nanostructured molybdenum trioxide-based biocompatible sensor platform for breast cancer biomarker detection

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Studies relating to development of the emerging nanostructured molybdenum trioxide ($nMoO_3$) based biocompatible label free biosensing platform for breast cancer detection are reported. The structural and morphological studies of the synthesized $nMoO_3$ nanorods are investigated by XRD, SEM, XPS and TEM techniques. This biocompatible 1-D $nMoO_3$–based biosensing platform exhibited high sensitivity (0.904 μA mL ng^{-1} cm^{-2}), wide linear detection range (2.5–110 ng mL^{-1}) and a lower detection limit as 2.47 ng mL^{-1} towards HER^{-2} detection. The results obtained using this sensor platform on serum samples of breast cancer patients were validated ELISA. DOI:org/10.1557/mrc.2018.182

PdAg-decorated three-dimensional reduced graphene oxide-multi-walled carbon nanotube hierarchical nanostructures for high-performance hydrogen peroxide sensing

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High-performance electrochemical hydrogen peroxide ($H_2O_{2)}$ sensors based on PdAg nanoparticle-decorated reduced graphene oxide (rGO) and multi-walled carbon nanotube (MWCNT) hybrids were developed. The nanostructures were characterized using transmission electron microscopy, scanning electron microscopy, energy-dispersive spectroscopy, thermogravimetric analysis, Fourier transform spectroscopy, and x-ray diffraction techniques. It was found that introduction of MWCNT in the catalyst layer improved the sensitivity and widened the linear range. Sensitivities of 393.2, 437.1, and 576.6 μA/mM/cm^2 were obtained for PdAg/rGO–MWCNT (2:1), PdAg/rGO–MWCNT (1:1), and PdAg/rGO–MWCNT (1:2), respectively. Furthermore, hierarchical structure of rGO–MWCNT nanohybrids enabled the detection of H_2O_2 up to 80 mM. DOI:org/10.1557/mrc.2018.82

Graphene-DNAzyme-based fluorescent biosensor for *Escherichia coli* detection

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The use of a new DNAzyme/graphene hybrid material as a biointerfaced sensing platform for optical detection of pathogenic bacteria is explored. The hybrid consists of a colloidal graphene nanomaterial and an *Escherichia coli*-activated RNA-cleaving DNAzyme and is prepared via non-covalent self-assembly of the DNAzyme onto the graphene surface. Exposure of the hybrid material to *E. coli*-containing samples results in the release of the DNAzyme, followed by the cleavage-mediated production of a fluorescent signal. Given that specific RNA-cleaving DNAzymes can be created for diverse bacterial pathogens,

direct interfacing of graphene materials with such DNAzymes represents a general and attractive approach for real-time, sensitive, and highly selective detection of pathogenic bacteria. DOI:org/10.1557/mrc.2018.97

PROSPECTIVES

Interplay and coupling of electric and magnetic multipole resonances in plasmonic nanoparticle lattices

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Lattice resonances in nanoparticle arrays recently have gained a lot of attention because of the possibility to produce spectrally narrow resonant features in transmission and reflection as well as significantly increase absorption in the structures. Most of the efforts so far have been put to study these lattice resonances in dipole approximation. However, the recent research shows that higher multipoles not only produce resonant feature but are also involved in cross-coupling, affect each other, and induce a magnetoelectric response. The recent achievements in studying interplay and coupling of different multipoles in periodic nanoparticle arrays and further progress of the field are reviewed. DOI:org/10.1557/mrc.2018.112

A review on phospholipid vesicles flowing through channels

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The flow of particles through confined volumes has appeared under different contexts in nature and technology. Some examples include the flow of red blood cells or drug delivery vehicles through capillaries, or surfactant-based particles in nano- or microfluidic cells. The molecular composition of the particles along with external conditions and the characteristics of the confined volume impact the response of the particle to flow. This review focuses on the problem of phospholipid vesicles constrained to flowing in channels. The review examines how experimental and computational approaches have been harnessed to study the response of these particles to the flow. DOI:org/10.1557/mrc.2018.118

Vapor phase infiltration: from a bioinspired process to technologic application, a prospective review

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Biomineralization is a natural concept to alter the mechanical properties of soft matter. Mimicking this concept became desirable with a resulting great variety of approaches toward realizing functional hybrid materials. Vapor-phase infiltration (VPI), a solvent-free approach, is complementary to solution-based processes and often provides hybrid materials with a different chemical nature. This article overviews the evolution of VPI from a curiosity-driven alternative way to mimic biomineralization toward its application in functional materials design. Even though still in infancy, the rapidly growing interest shows promise for upcoming innovative applications of VPI in a great variety of research and development directions. DOI:org/10.1557/mrc.2018.126

Molecular valves for colloidal growth of nanocrystal quantum dots: effect of precursor decomposition and intermediate species

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The ability to manipulate matter on the nanometer length scale is an important scientific goal, and the progress in the field of colloidal nanocrystal (NC) growth in the past decades has opened avenue for controlled synthesis of nanoscale materials with many unique physical properties that could enhance existing technologies or give rise to entirely new technologic applications. At the center of the progress is ever-increasing understanding on molecular interactions within colloidal synthesis, in which nucleation and growth each plays a critical role in the control of size, shape, morphology, and structure of NCs. Semiconductor NCs in quantum confinement regime, referred to as quantum dots (QDs), highlight the importance of such control over geometric parameters, since QDs exhibit size- and shape-dependent optical properties. Important aspects that govern QDs growth in the context of (i) precursor conversion chemistry, and (ii) intermediate species including molecular complex and clusters are demonstrated. Advances in understanding the growth chemistry of QDs have proved the significance of how precursors decompose and produce intermediate species. Recent progress in regards to the synthetic chemistry of colloidal QDs and challenges and promises in the controlled large-scale synthesis of QDs are reviewed. DOI:org/10.1557/mrc.2018.129

Nanohybrid-sensitized photoelectrochemical cells for solar-to-hydrogen conversion

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This article reviews the semiconductor and metal-based nanohybrid-sensitized photoelectrochemical (PEC) cells for hydrogen generation from water. The nanoscale hybridization of sensitizers in the photoanode can enhance light harvesting, interfacial charge transfer, charge separation, and induce a catalytic effect in dependence on the kind of the components and interfacial junction state. Subsequent

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to the introduction, second and third sections present the basic structure and design of the nanohybrid-sensitized PEC cell. Fourth section deals with the effect of the interfacial bond between quantum dots and TiO_2 on the electron injection process. Fifth section mainly describes the formation of heteroepitaxial junction between the components of nanohybrids. In the sixth section, the state-of-the-art nanohybrid-sensitized PEC cells are treated with a particular emphasis placed on the interface state. DOI:org/10.1557/mrc.2018.137

Titania-based electrospun nanofibrous materials: a new model for organic pollutants degradation

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Effective degradation of organic pollutants in wastewater is of great importance to the environment and human society. TiO_2-based electrospun nanofibrous materials combining the properties of the large specific surface area, high aspect ratio, tunable compositions and structures, as well as easy to recycle, show great promise for the efficient removal of organic pollutants. In this Prospective paper, the recent progress in the degradation of organic water contaminants over visible-light-responsive TiO_2-based nanofibrous materials is summarized, with emphasis on the strategies for improving the visible-light photocatalytic activity of TiO_2-based nanofibrous materials. Finally, the current challenges and future outlook in this field are discussed. DOI:org/10.1557/mrc.2018.139

Review and perspective on ferroelectric HfO_2-based thin films for memory applications

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The ferroelectricity in fluorite-structure oxides such as hafnia and zirconia has attracted increasing interest since 2011. They have various advantages such as Si-based complementary metal oxide semiconductor-compatibility, matured deposition techniques, a low dielectric constant and the resulting decreased depolarization field, and stronger resistance to hydrogen annealing. However, the wake-up effect, imprint, and insufficient endurance are remaining reliability issues. Therefore, this paper reviews two major aspects: the advantages of fluorite-structure ferroelectrics for memory applications are reviewed from a material's point of view, and the critical issues of wake-up effect and insufficient endurance are examined, and potential solutions are subsequently discussed. DOI:org/10.1557/mrc.2018.175

Boosting interfacial charge transfer for efficient water-splitting photoelectrodes: progress in bismuth vanadate photoanodes using various strategies

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Bismuth vanadate ($BiVO_4$) is regarded as a viable material for water oxidation due to various benefits such as visible light absorption, low production cost, and resistance to photocorrosion. Recently, numerous attempts have been adopted to improve the performance of $BiVO_4$. The important strategies that have been made for improving the performance of the photoanode material, such as fabricating nanostructured electrode, controlling reacting facet, stacking with other materials, utilizing plasmonics, loading co-catalyst, and controlling the interfacial band bending with ferroelectrics are highlighted. Taking advantage of the strategies, highly efficient $BiVO_4$ photoelectrodes could be demonstrated. The perspective of $BiVO_4$-based photoanodes are discussed. DOI:org/10.1557/mrc.2018.106

Dirac plasmons and beyond: the past, present, and future of plasmonics in 3D topological insulators

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Studies of unique plasmonics in topological insulators (TIs) are reviewed, describing exfoliation and deposition synthesis approaches. TI materials have substantially improved: it is now possible to grow samples with few trivial electrons and controllable doping. The theory behind the unique behavior of the coupled, 2D Dirac plasmons and experimental efforts are described, noting that Dirac plasmons have been conclusively demonstrated in TIs and they show remarkable properties including long lifetimes, large mode indices, and huge modulation depths. Opportunities for high-quality materials can be obtained, including spin and nanoparticle plasmons are explored. DOI:org/10.1557/mrc.2018.173

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